Fishery Management Report No. 10-46

A Seasonal Summary of the Hidden Lake Sockeye Salmon Stocking Project and Related Criteria for 2009

by

Steven E. Thomsen

December 2010

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY MANAGEMENT REPORT NO. 10-46

A SEASONAL SUMMARY OF THE HIDDEN LAKE SOCKEYE SALMON STOCKING PROJECT AND RELATED CRITERIA FOR 2009

by
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The Kodiak Regional Aquaculture Association (KRAA) funds the general operations of the Hidden Lake sockeye salmon stocking project and Pillar Creek Hatchery. The Division of Commercial Fisheries provides biological oversight and evaluation in the management of returning adult runs to the enhanced or rehabilitated systems associated with hatchery stocking projects.

The Fishery Management Reports series was established in 1989 by the Division of Sport Fish for the publication of an overview of management activities and goals in a specific geographic area, and became a joint divisional series in 2004 with the Division of Commercial Fisheries. Fishery Management Reports are intended for fishery and other technical professionals, as well as lay persons. Fishery Management Reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm. This publication has undergone regional peer review.

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ABSTRACT

A sockeye salmon *Oncorhynchus nerka* enhancement stocking project was initiated on the Hidden Lake system on Afognak Island in 1987 to provide increased harvest opportunities for fishermen in the Kodiak Management Area. Because Hidden Lake lies within the boundaries of the Kodiak National Wildlife Refuge, the project is subject to U.S. Fish and Wildlife Service oversight and guiding principles. To ensure that the project remains compatible with the Kodiak National Wildlife Refuge mission, the Alaska Department of Fish and Game monitors specific criteria outlined in the Hidden Lake Management Plan. Specific attributes which must be monitored are lake nutrient concentrations (total nitrogen, phosphorus, ammonia, and chlorophyll *a*), zooplankton size, density and biomass, juvenile stocking, and adult harvest estimates.

The 2009 water quality data collected from an established station in the lake resulted in an average total nitrogen to total phosphorus ratio of 188:1, a total ammonia level of 5.8 μg/L, and a chlorophyll-*a* level of 0.48 μg/L. The zooplankton data revealed an average seasonal *Diaptomus* to *Cyclops* density ratio of 0.01:1, a weighted copepod biomass of 2.50 mg/m^3, a *Bosmina* to *Daphnia* density ratio of 8.73:1, a weighted cladoceran biomass of 3.12 mg/m^3, and a weighted *Bosmina* size (average length) of 0.44 mm. A total of 254,030 juveniles were stocked in 2009. A total of 6,508 adult sockeye salmon were harvested in the Foul Bay Special Harvest Area and reported on commercial fish harvest tickets.

The 2009 Hidden Lake stocking project met all but one criteria specified in the Hidden Lake Management Plan (Total Nitrogen to Total Phosphorus ratio) and was compatible with Kodiak National Wildlife Refuge purposes.

Key words: Hidden Lake, Foul Bay, Special Harvest Area, *Oncorhynchus nerka*, sockeye salmon, stocking, Kodiak National Wildlife Refuge, U.S. Fish and Wildlife Service, Kodiak Regional Aquaculture Association, Special Use Permit, limnology, zooplankton, chlorophyll *a,* ADF&G, KNWR, FBSHA, USFWS, HLMP, *Cyclops*, *Diaptomus*, *Bosmina*, *Daphnia*, *Holopedium*.

INTRODUCTION

Hidden Lake (58°23' N lat, 152°42' W long) is located on the northwest side of Afognak Island, approximately 72 km northwest of the city of Kodiak (Figure 1). The lake is 4.4 km long, up to 0.6 km wide, and has a surface area 1.9 km^2 (Figure 2). Hidden Lake is at an elevation of 68.0 m, has a mean depth of 10.8 m, and a maximum depth of 42.0 m. The Hidden Lake outlet stream (Hidden Lake Creek) is approximately 2.4 km long and empties into the north arm of Foul Bay. Resident fish in Hidden Lake include rainbow trout *O. mykiss*, Dolly Varden char *Salvelinus malma*, three spine stickleback *Gasterosteus aculeatus*, and freshwater sculpin *Cottus aleuticus* (Honnold and Schrof 2001).

Hidden Lake was devoid of salmon due to a waterfall, impassable to anadromous fish, located approximately 1.6 km upstream from the ocean. The stocking project was designed to utilize the abundant zooplankton population in the lake to produce sockeye salmon smolt that would emigrate to the ocean and return as adults to Foul Bay (Honnold and Schrof 2001; Figure 1). Adult sockeye salmon runs returning to Foul Bay would then be harvested in a terminal area, which would reduce possible interactions with wild stocks. The project has allowed for evaluation of the response of the lake’s zooplankton community to predation by juvenile salmon, monitoring of freshwater growth of the stocked sockeye salmon, and fry-to-adult survival.

Hidden Lake is located within the boundaries of the Kodiak National Wildlife Refuge (KNWR) and the activities associated with the sockeye salmon stocking project are therefore subject to U.S. Fish and Wildlife Service (USFWS) and KNWR guiding principles and conditions. Such conditions are described in the Hidden Lake Management Plan (HLMP; Chatto 2002) and are permitted under the special conditions described in the Hidden Lake Special Use Permit (HLSUP). In 1992, the ADF&G, in cooperation with the Kodiak Regional Aquaculture Association (KRAA), submitted proposals to the USFWS to stock sockeye salmon into Hidden

Lake (Chatto 2002; White 1992). The KNWR prepared an Environmental Assessment (EA) for the proposed project, which resulted in a Finding of No Significant Impact (FONSI). A temporary HLSUP for the Hidden Lake project was issued to the ADF&G by the KNWR in 1992, to allow the project to proceed until a thorough review of the baseline data could be completed and a comprehensive management plan developed that would contain criteria specific to Hidden Lake. In 2001, the ADF&G consolidated existing information (excluding brown bear and wildlife studies) from the Hidden Lake stocking project into one document (Honnold and Schrof 2001), which was then used as a reference to write the original KNWR HLMP (Chatto 2002). The HLMP was authorized by KNWR in April 2002 and the ADF&G has been issued a 5-year renewable HLSUP twice (2002, 2007) to continue the project in Hidden Lake.

Juvenile sockeye salmon have been stocked into Hidden Lake annually since 1992 (Finkle and Byrne 2010). The returning adult sockeye salmon are harvested in the Foul Bay Special Harvest Area (FBSHA; Figure 1). The ADF&G has annually monitored the fishery and attempted to sample a portion of the sockeye salmon commercial catch since 1995. Limnological data has been collected at Hidden Lake since 1987 (Honnold and Schrof 2001). Zooplankton density and biomass and water chemistry and nutrient parameters are collected yearly as part of the HLMP (Appendices A1, A2, A3, and A4).

Conservative stocking levels were recommended to maintain stable nutrient and zooplankton levels in Hidden Lake and support a long-term enhancement project (Kyle 1996). In 2001, Honnold and Schrof (2001) reviewed zooplankton interactions in Hidden Lake and concluded that juvenile sockeye salmon stocking had little effect on zooplankton composition when stocking levels were lower than 300,000 juveniles. Honnold and Schrof (2001) also noticed a decline in *Diaptomus* abundance but regarded it a result of natural variation.

This report summarizes the 2009 and historical (initiated in 1987) project data collected to monitor the Hidden Lake sockeye salmon *Oncorhynchus nerka* stocking project and fulfill the reporting requirements as outlined in the HLMP and HLSUP, ensuring that the project remains compatible with the KNWR purposes (Kyle 1996).

MANAGEMENT PLAN MONITORING CRITERIA

The purpose of the HLMP is to outline how the various components of the lake stocking project will be managed to remain compatible with the KNWR's mission and to serve as a reference document to guide any proposed changes to project operations (Chatto 2002).

Monitoring guidelines with specific limnological and fishery criteria were established from data collected at Hidden Lake from 1992 to 1999 (Honnold and Schrof 2001; Table 1). If measurements fall outside the criteria specified in the HLMP and HLSUP for any given attribute for two or more years, then the stocking project may need adjustments to meet the guidelines and purposes of the KNWR (Chatto 2002). Specific attributes which must be monitored are lake nutrient concentrations (total nitrogen, phosphorus, ammonia, and chlorophyll *a*), zooplankton size, density and biomass, juvenile stocking, and adult harvest estimates (Table 1).

MANAGEMENT PLAN OBJECTIVES

The objectives are:

1. Monitor water quality in Hidden Lake to ensure compatibility with the HLMP criteria;
2. Monitor zooplankton in Hidden Lake to ensure compatibility with the HLMP criteria;

3. Stock juvenile sockeye salmon at densities based on the analysis of current and historical limnological data; and
4. Document the commercial salmon harvest within the FBSHA to evaluate supplemental commercial harvest.

METHODS

LIMNOLOGICAL MONITORING

To follow HLMP guidelines, ADF&G monitors specific limnological and fishery attributes of the lake (Chatto 2002; Table 1). Attributes measured are total nitrogen (TN) to total phosphorus (TP) ratio, total ammonia (TA), chlorophyll *a* (Chl-*a*), *Diaptomus* to *Cyclops* density ratio, copepod biomass, *Bosmina* to *Daphnia* density ratio, cladoceran biomass, and cladoceran (*Bosmina*) average size. In addition, ADF&G tracks fry stocking levels, reports the number of salmon harvested in the FBSHA, and measures other limnological attributes: filterable reactive phosphorous (FRP; orthophosphate), total filterable phosphorous (TFP), Total Kjeldahl Nitrogen (TKN), Nitrate + Nitrite (N+N; No^3+No^2), Phaeophytin *a*, and the abundance and size of zooplankton not specifically covered in the HLMP. Total Nitrogen is derived by adding TKN and N+N.

Lake Sampling Protocol

To obtain the limnology data, ADF&G sampled Hidden Lake four times from May to September at approximately four to five week intervals. At the lake, a sampling station was established in the deepest basin and marked at the lake surface by a buoy set with Global Positioning System (GPS) equipment (Figure 2). Prior to 2000, water samples were collected from the epilimnion (at a depth of 1 m) and the hypolimnion (at a depth ≥25 m). After 2000, water samples were only collected from the epilimnion to reduce sampling costs. Samples were collected following standard ADF&G sampling procedures (Foster et al. 2009 A; Thomsen 2008; Koenings et al. 1987).

Water samples were collected with a 4 L Van Dorn™ bottle[1], and the samples were transferred into pre-cleaned polyethylene carboys, which were kept cool and dark until processed at the laboratory in Kodiak. Vertical zooplankton tows were made at each station using a 0.2 m diameter conical net with 153 µm mesh. The net was pulled manually at a constant speed (~0.5 m sec^{-1}) from approximately 1 m off the lake bottom to the surface. The contents from each tow were transferred into a 125 ml polyethylene bottle and preserved in 10% neutralized formalin.

General Water Chemistry and Nutrients

Unfiltered water was analyzed for TP, TKN, pH, and alkalinity. Sample water was filtered through a rinsed 4.25 cm diameter Whatman™ GF/F filter pad and stored frozen in phosphate free soap-washed and acid washed polyethylene bottles. Filtered water was analyzed for TFP, FRP, N+N, and TA. TP, TFP, FRP, N+N, and TA were analyzed using a Spectronic Genesys 5 Spectrophotometer (SG5).

TP was analyzed using the potassium persulfate-sulfuric acid digestion method described in Thomsen (2008) and Koenings et al. (1987) that was adapted from methods in Eisenreich et al.

[1] Product names used in this report are included for scientific completeness, but do not constitute product endorsement.

(1975). Unfiltered frozen water samples were sent to the South Dakota University laboratory for TKN analysis using the EPA 351.3 (Nesslerization) method. The pH of water samples was measured with a Corning ™ 430 meter, while alkalinity (mg L^{-1} as $CaCO_3$) was determined from 100 ml of unfiltered water titrated with 0.02 N H_2SO^4 to a pH of 4.5 and measured with a Mettler Toledo ™ Seven Easy pH meter.

TFP was determined using the same methods as those for TP utilizing filtered water. FRP was determined using the potassium persulfate-sulfuric acid method described in Thomsen (2008) and Koenings et al. (1987). Samples for N+N were analyzed using the cadmium reduction column method described in Thomsen (2008) and Koenings et al. (1987). TA was determined using the phenol-sodium hypochlorite method described in Thomsen (2008) and Koenings et al. (1987). Total nitrogen, the sum of TKN and N+N, were calculated for each sample in addition to the ratio of total nitrogen to total phosphorus.

Chlorophyll *a*

For Chl-*a* analysis, 1.0 L of water from each sample was filtered through a Whatman™ GF/F filter under 15 psi vacuum pressure. Approximately 5 mL of magnesium chloride ($MgCO_3$) were added to the final 50 mL of water near the end of the filtration process for sample preservation. Filters were stored frozen in individual plexiglass slides until analyzed. Filters were then ground in 90% buffered acetone using a mortar and pestle, and the resulting slurry was refrigerated in separate 15 mL glass centrifuge tubes for 2 to 3 hours to ensure maximum pigment extraction. Pigment extracts were centrifuged, decanted, and diluted to 12 mL with 90% acetone (Koenings et al. 1987; Thomsen 2008). The extracts were analyzed using a SG5 Spectrophotometer using methods described in Thomsen (2008) and Koenings et al. (1987).

Zooplankton

For zooplankton analysis, cladocerans and copepods were identified according to taxonomic keys by Thorp and Covich (2001), Wetzel (1983), and Edmondson (1959). Zooplankton samples were measured in triplicate 1-mL subsamples taken with a Hansen-Stempel pipette and placed in a Sedgewick-Rafter counting chamber. Lengths from a minimum of 15 animals of each species or group (typically animals are grouped at the genus or species level) were measured to the nearest 0.01 mm, a student's t-test was then employed (Thomsen 2008; Koenings et al. 1987), and the mean was calculated. Density is the number of individuals per unit volume and reported in this publication as the number per meter cubed (no./m^3). Biomass was estimated using density and weight, using species-specific linear regression equations between length and dry weight derived by Koenings et al. (1987).

STOCKING

Stocking densities for Hidden Lake were based on in-season zooplankton biomass prior to the hatchery egg takes (May through July; Finkle and Byrne 2009). Afognak Lake sockeye salmon eggs were collected in early August of 2008 by Pillar Creek Hatchery (PCH) personnel using standard fish culture procedures (ADF&G 1994). Eggs were flown back to Kodiak, incubated and reared at PCH, and juvenile salmon were aerially released into Hidden Lake via fixed wing aircraft.

HARVEST AND ESCAPEMENT MONITORING

ADF&G personnel monitored the commercial harvest within the FBSHA during the fishery opening while stationed on board the *M/V K-HI-C* (Figure 1). Monitoring goals were designed to include the assessment of sockeye salmon run strength, recording the fishing effort, estimating the commercial catch by species, and sampling a portion of the sockeye salmon catch for age data (Foster et al. 2009b; Honnold and Schrof 2001). In 2009, ADF&G personnel collected harvest and age, sex, and length (ASL) data from the sockeye salmon harvest. No escapement surveys of Hidden Creek were conducted in 2009.

RESULTS

LIMNOLOGICAL MONITORING

Total Nitrogen to Total Phosphorus Ratio

The 2009 total nitrogen to total phosphorus molar ratio (TN:TP) in Hidden Lake of 188:1 did not meet the desired criterion (≤106:1) specified in the HLMP (Tables 1 and 2; Appendix A.3). This TN:TP ratio was well above the 1992 to 2008 average of 90:1.

Total Ammonia

The 2009 seasonal average concentration of ammonia in Hidden Lake was 5.8 μg/L (Tables 1 and 3; Appendix A3). This ammonia concentration was slightly below the 1992 to 2008 average but within the range of standard deviation (6.9 μg/L; ±SD 4.0; Table 3) and well below the criterion of ≤16.2 μg/L specified in the HLMP (Table 1).

Chlorophyll *a*

The seasonal mean Chl-*a* concentration in Hidden Lake was 0.48 μg/L (Tables 1 and 3). As noted in Table 1, the Chl-*a* concentrations met the HLMP criteria of ≥0.17 μg/L (Table 1). The 2009 Chl-*a* concentration was below the 1992 to 2008 average (0.61 μg/L) but within the standard deviation (SD ±0.3).

Copepod Biomass

The average copepod biomass in 2009 was 2.50 mg/m^3 and the density was 1,234/m^3 (Table 5). The 2009 copepod biomass met the HLMP criteria of ≥ 0.40 mg/m^3 (Table 1). The average copepod biomass from 1992 to 2008 was 3.76 mg/m^3, slightly higher than in 2009, and the density was 2,217/m^3, considerably higher than in 2009 (Table 4). Mean copepod density is not specified as a criteria in the HLMP.

Diaptomus to *Cyclops* Density Ratio

The *Diaptomus:Cyclops* density ratio of 0.01:1 met the minimum criterion (≥0.01:1) specified in the HLMP (Tables 1 and 5). The average ratio from 1992 to 2008 was 0.03:1.

Cladoceran Biomass

There was an average cladoceran biomass of 3.12 mg/m^3 and an average density of 1,620/m^3 in Hidden Lake in 2009 (Tables 4 and 6). The 2009 biomass was above the minimum criterion of ≥2.20 mg/m^3 specified in the HLMP (Tables 1 and 4). Average biomass in 2009 was less than the average biomass from 1992 to 2008 (4.35 mg/m^3; Tables 4 and 6) while, the average density was greater (1,225 mg/m^3; Tables 4 and 6). Mean cladoceran density was not specified as criterion in the HLMP.

Bosmina to *Daphnia* Density Ratio

The *Bosmina:Daphnia* density ratio in 2009 of 8.73:1 was above the minimum criterion (≥0.17:1) specified in the HLMP (Tables 1 and 6). The average ratio from 1992 to 2008 was notably less (4.56:1; Table 6).

Cladoceran (*Bosmina*) Size

The cladoceran *Bosmina* averaged 0.44 mm in length in 2009 which met the criterion (>0.40 mm) specified in the HLMP (Tables 1 and 7). The average size of *Bosmina* from 1992 to 2008 was 0.47 mm.

Total Zooplankton

The 2009 seasonal mean zooplankton density in Hidden Lake was 2,854/m^3 and the biomass was 5.62 mg/m^3 (Table 4). The 2009 zooplankton density and biomass were less than the averages from 1992 to 2008 (3,442/m^3; 8.1 mg/m^3; Table 4; Figure 3). Total zooplankton density and biomass were not specified as criteria in the HLMP but are presented here because they are easily calculated from the data and relevant to the discussion.

STOCKING

Juvenile sockeye salmon were stocked in Hidden Lake on two occasions in 2009. Approximately 149,300 fry (average weight of 0.4 g) were stocked on June 17 and 104,730 pre-smolt (average weight of 9.2 g) were stocked on October 2 (Table 8). This stocking level (254,030) is slightly below the average (299,824) number of sockeye salmon stocked from 1992 to 2008 (Table 8; Figure 3).

At levels stocked above 300,000 juvenile sockeye salmon, zooplankton biomass decreased and at levels stocked below 300,000 juvenile sockeye salmon, zooplankton biomass increased (Tables 4, 5, 6, and 8).

SMOLT MONITORING

Smolts were not monitored in 2009. In past years, a sockeye salmon smolt project was conducted (1993-2002), coho salmon juveniles were stocked (1988-1989, 1991), and hydroacoustics surveys were conducted ((1994-2001) in Hidden Lake (Appendices B1, B2, and B3).

HARVEST MONITORING

During 2009, commercial salmon were harvested on eight days in the FBSHA in June (Table 9). In total, 1 Chinook salmon (*O. tshawytscha*), 6,508 sockeye salmon, 0 coho salmon (*O. kisutch*), 3 pink salmon (*O. gorbuscha*) and 1 chum salmon (*O. keta*) were harvested in the FBSHA in 2009. The sockeye salmon harvest of 6,508 was well below the 1995 to 2008 average of 23,738 (Table 10). The commercial harvest of non-targeted salmon species was less than historical averages (1995–2008; 33 Chinook; 3 coho; 199 pink; and 165 chum; Table 10). The commercial fishery in the FBSHA closed on July 10.

On-site ADF&G monitoring staff collected 328 sockeye salmon scales from the commercial fishery in FBSHA in 2009. Sockeye salmon age composition from the FBSHA is provided in

Table 11. The 2009 age components were as follows: age 1.3 (42.4%), age 1.2 (35.7%), age 1.1 (10.1%), age 2.2 (4.3%), and age 2.1 (0.3%). Historically, the age 1.2 component comprises 62.5% and the age 1.3 component comprises 29.7% of the harvest (Table 11).

DISCUSSION

Relationships surrounding "whole lake" interactions and smolt production are complex. Hidden Lake, as a barren system, provides a unique opportunity to explore these complex interactions. Barren lakes typically have a lower productivity than lakes with returning adult sockeye salmon due to a lack of marine derived nutrient input from returning adult sockeye salmon and an a reliance instead on allochthonous inputs as the entire source of nutrients (Kyle 1996; Sweetman 2001). As a stocked lake, the juvenile salmon density, size, and age at stocking into Hidden Lake can be controlled. The adult returns and age structure are estimated annually when the commercial harvest in the FBSHA is sufficient. This report marks the first exploratory look at some of the contributing factors affecting smolt production. A more in-depth look into these and other relationships that affect productivity needs to be addressed in future reports.

NUTRIENT MONITORING

Mean seasonal water chemistry and nutrient values in Hidden Lake have remained relatively constant over the twenty year data set (1990–2009). Despite annual fluctuations, the seasonal means for these nutrients were within criterion ranges found in oligotrophic lakes (Honnold et al. 1996).

The elevated TN:TP ratio found in Hidden Lake in 2009 indicated limited phosphorus concentrations, while nitrogen concentrations were elevated. Although the TN:TP ratio was outside of the criterion specified in the HLMP, the ratio was within ranges found in oligotrophic lakes (Table 1; Honnold et al. 1996). Additionally, Chl-*a* concentrations in 2009 were slightly below average concentrations (1992-2008) but within the normal range found in Hidden Lake, indicating sufficient phosphorus concentration for Chl-*a* production (Table 3).

PRIMARY PRODUCTION

Primary production in Hidden Lake was measured by determining the phytoplankton standing crop (Chl *a*) during the ice free season. Historically, Hidden Lake Chl-*a* concentrations have remained relatively stable and within ranges for oligotrophic lakes in Alaska (Honnold and Schrof 2003).

Honnold and Schrof (2001) hypothesized that mean Chl-*a* concentrations increased slightly since stocking began. Data collected at Hidden Lake since 1999 corroborates this finding. The increased Chl-*a* concentration was likely a result of decreased grazing by zooplankton, increasing the standing stock of phytoplankton (Honnold and Schrof 2001).

TEMPERATURE

Water temperatures are commonly known to play a key role in primary production (Sommer and Lengfellner 2008; Shutter and Ing 1996). Increases in lake temperatures typically contribute to an increase in production at each trophic level, thus increasing the abundance of phytoplankton and the potential for increasing zooplankton abundance and juvenile sockeye salmon abundance and body size (George and Harris 1985).

A cursory review of the available data suggested that phytoplankton production (using Chl *a* only) in Hidden Lake increased little with warmer spring surface lake temperatures (Table 3; Appendix A5). Greater summer surface temperatures appeared to increase the abundance of most cladocerans and copepods in Hidden Lake (Tables 4, 5, and 6; Appendix A5) but there was considerable variation in yearly responses. The varied stocking strategies and stocking densities employed over the project likely play a role in some of the variation and make definitive conclusions difficult. Interestingly, *Epischura* density increased with increased fall temperatures. Further exploration in this area may prove helpful if phytoplankton samples are analyzed (species, density, and biomass) and the frequency of temperature data collection is increased.

Juvenile sockeye salmon in Alaska lakes have been shown to increase in size when lake temperatures are greater (Edmundson and Muzumder 2001). Smolt data for Hidden Lake was limited to data collected from 1993 to 2002 (Appendix B1). Although temperature and smolt data were limited, the smolt data from Hidden Lake should be relevant to approximate smolt growth and potential survival for years without smolt data. In Hidden Lake, greater fall bottom temperatures coincided with increased age-1. and age-2. smolt growth (condition, weight, and length; Appendices B1 and B4).

ZOOPLANKTON MONITORING

Cladocerans

In most oligotrophic lakes in Alaska, cladocerans are generally less abundant than copepods (Kyle 1996). Hidden Lake zooplankton abundance fluctuated between copepod and cladoceran dominance, although copepods were the dominant biomass in most years. Even though cladocerans comprise a lower biomass than copepods, they are generally considered a preferred food item for juvenile sockeye salmon and are typically exploited at a greater rate (Kyle 1996). This greater exploitation rate reduces cladoceran abundance and length more quickly than that of copepods (Kyle 1996). This rapid response to predation from juvenile sockeye salmon means cladocerans are commonly used as an indicator for predation pressure and is the rationale for a minimum length requirement in the HLMP for *Bosmina* in Hidden Lake.

The response cladocerans exhibit to juvenile sockeye salmon stocking in barren lakes can be quite variable. Previous stockings into Hidden Lake were followed by substantial declines in zooplankton abundance and length but quickly rebounded following the initial decline (Honnold and Schrof 2001). Kyle (1996) speculated that zooplankton populations in barren lakes are less able to tolerate predation and may need time to develop appropriate response mechanisms in order to avoid excess predation. In Hidden Lake, the abundance of most cladocerans decreased rapidly when juvenile sockeye salmon stocking levels were increased (Tables 6 and 8). Conversely, *Holopedium* abundance exhibited little change when stocking was increased, indicating lower predation by juvenile sockeye salmon.

Predation from planktivores has been shown to influence the length of zooplankton (Carpenter et al. 1985; Kyle 1996). Carpenter (1985) proposed that planktivores (juvenile sockeye salmon, predatory zooplankton, etc.) tend to select the largest prey they can consume. As sockeye salmon grow, they tend to target larger zooplankton to increase their efficiency of energy transfer (Kyle 1992). Because populations of planktivores fluctuate, the length of zooplankton preyed upon also varies. In Hidden Lake, the mean length of *Daphnia* decreased when sockeye salmon stocking increased. On the other hand, *Bosmina* and *Holopedium* showed no change in size when stocking levels were increased (Tables 7 and 8).

Juvenile sockeye salmon have been stocked into Hidden Lake at various life stages (fry, fingerling, and pre-smolt). Similar to Spiridon Lake, pre-smolt stocked into Hidden Lake affected zooplankton abundance to a greater extent than stocked fry. Generally, the combination of increased fry stocking with decreased pre-smolt stocking into Hidden Lake increased predation on cladocerans and decreased predation on copepods. Conversely, the greater the pre-smolt density stocked (and lower fry), the greater the predation on copepods (Tables 4–8).

Robust smolt body size is typically indicative of a healthy lake system not exceeding the rearing capacity (Honnold and Schrof 2001). The condition of sockeye salmon smolt appeared independent of the length of cladocerans (Table 7; Appendix B1). On the other hand, when *Bosmina* abundance increased, the condition of age-1. sockeye salmon smolt increased (Tables 4 and 6; Appendix B1). Increased *Daphnia* and *Holopedium* abundance appeared to produce little change in the condition of sockeye salmon smolt (Tables 4 and 6; Appendix B1). It also appears that juvenile sockeye salmon may have an upper threshold where their length and weight no longer increased as *Bosmina* abundance increased. Age-2. sockeye salmon smolt have historically comprised a small proportion of the outmigration in Hidden Lake (Appendix B4). Age-2. sockeye salmon smolt showed similar trends to age-1. sockeye salmon smolt growth, but increased mean cladoceran length impacted age-2. sockeye salmon smolt growth to a greater extent (Tables 4 and 6; Appendix B1).

Copepods

Zooplankton biomass in Hidden Lake was predominately composed of copepods, which are typically more tolerant to predation and have a greater ability to buffer environmental conditions than cladocerans. Their tolerance can be attributed to a greater ability to evade predators, more efficient feeding, the ability to exist in a state of diapause, and a greater adaptation to the cold water environment (Hairston and Munns 1984; Kyle 1996). Conversely, copepods reproduce slower than cladocerans limiting their ability to rebound as quickly to predation (Kyle 1990).

In Hidden Lake, copepod biomass declined less than cladoceran biomass when stocking densities were increased (Tables 4, 5, and 8). Both *Cyclops* and *Epischura* exhibited a modest decline in biomass with increased stocking. Alternately, the biomass of *Diaptomus* declined significantly after juvenile stocking began in 1992 (Table 5). After the initial juvenile stocking, the density of *Diaptomus* fell short of the minimum criteria specified in the HLMP for the next eleven years. Since that time, the HLMP criteria were met in five of the last six years (Tables 5, 7; Appendix A4).

The stocking strategy of juvenile sockeye salmon appeared to have impacted the predation on zooplankton in Hidden Lake. The stocking of pre-smolt into Hidden Lake appeared to have affected zooplankton abundance to a greater extent than fry. In general, pre-smolt appeared to crop small copepods; as shown by the decreased abundance and increased length of *Cyclops* when pre-smolt were stocked. *Epischura* and *Diaptomus* exhibited no similar trends. Alternately, fry predominately cropped the cladocerans (except *Daphnia*); as shown by the decreased abundance and increased lengths when fry were stocked. Cladoceran lengths were not noticeably affected when pre-smolt were stocked. Fingerlings were stocked into Hidden Lake at low densities on four occasions, making it difficult to draw any conclusions.

The condition of sockeye salmon smolt in Hidden Lake appeared unchanged when *Cyclops* abundance and length increased (Table 5; Appendices A4 and B1). Diaptomus were not detected in sufficient numbers to evaluate any effects on sockeye salmon smolt condition. On the other hand, *Epischura* appeared to influence or be influenced by many factors in Hidden Lake. The condition of age-1. sockeye salmon smolt improved when the length of *Epischura* decreased. The length and weight of age-1. sockeye salmon smolt were not noticeably improved when the length of *Epischura* decreased. One explanation for this contradicting outcome is that decreased predation by larger *Epischura* may have improved forage conditions on other zooplankton species for juvenile sockeye salmon. This may also indicate that *Epischura* was able to maintain a healthy ratio of length to weight in mediocre conditions. Alternately, age-2. sockeye salmon smolt condition increased when *Cyclops* biomass increased.

SMOLT MONITORING

Outmigrating sockeye salmon smolts have not been sampled from Hidden Lake since 2002 and rearing juveniles (overwintering) were estimated using hydroacoustics techniques from 1994 to 1999 and in 2001 (Appendices B1 and B3). These data provided for limited assessment of juvenile sockeye salmon production for the Hidden Lake enhancement project. Therefore, production was estimated using fry to adult sockeye salmon survival, averaging 7.1% since 1992 (Appendix B4). Spiridon Lake fry to adult sockeye salmon survival averaged slightly higher at 10.7%, since 1991.

JUVENILE STOCKING AND COMMERCIAL HARVEST

The previous assessment of Hidden Lake by Honnold and Schrof (2001) suggested a stocking threshold of 300,000 juvenile sockeye salmon. The addition of another eleven years of data analysis (1999 to 2009) seems to support their assessment.

The sockeye salmon commercial harvest from FBSHA has been at its lowest levels in recent years. The harvest has steadily increased in the last three years, mirroring increases in juvenile sockeye salmon released into Hidden Lake. A small number of sockeye salmon destined for Hidden Lake may have been intercepted in statistical area 251-40 during the commercial salmon fishery in June. Allocating Hidden Lake harvest from statistical area 251-40 is not possible with existing data.

CONCLUSIONS

Hidden Lake has supported a varying level of sockeye salmon stocking and an oscillating zooplankton population throughout the enhancement project (1990–2009). Recently increased juvenile stocking levels have resulted in an increased commercial harvest.

Nutrient and primary production data were all within a normal range for Hidden Lake and is typical for an oligotrophic lake. Based on previous studies and the preliminary findings within this report, lake temperature appears to have an influence on primary and secondary production. Given the possible importance of temperature, and its propensity to fluctuate (yearly and seasonally), finding suitable long-term alternative temperature data would be beneficial.

The stocking strategy of juvenile sockeye salmon appears to have impacted zooplankton levels in Hidden Lake. The stocking of pre-smolt appears to have affected zooplankton abundance to a greater extent than the stocking of fry. In general, pre-smolt appeared to prefer copepods as prey and fry preferred cladocerans as prey. At levels stocked above 300,000 juvenile sockeye salmon, zooplankton biomass decreased and at levels stocked below 300,000 juvenile sockeye salmon, zooplankton biomass increased.

A preliminary investigation of Hidden Lake data brings forward some interesting possible zooplankton interactions. In the interest of furthering understanding, we will continue to explore possible relationships in Hidden Lake. Future development of a limnology database will assist in the exploration of these and other relationships in Hidden Lake.

OUTLOOK FOR 2010

The brood source for Hidden Lake juvenile releases has primarily been from the Afognak Lake sockeye salmon stock. The projected releases of juvenile sockeye salmon into Hidden Lake in 2010 are 300,000 fry and 45,000 pre-smolt for a total release of 345,000 (Finkle and Byrne 2010). The preliminary stocking numbers may be adjusted if the in-season zooplankton findings warrant modification. All other operations and monitoring projects planned for 2010 are expected to be consistent with the 2009 monitoring goals and objectives.

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TABLES AND FIGURES

Table 1.–Hidden Lake monitoring criteria specified in the Hidden Lake Management Plan (HLMP) and limnological and fishery data, and the 2009 results.

HLMP monitoring criteria	HLMP Threshold	2009 results
Limnology Monitoring		
Mean Total Nitrogen : Total Phosphorous Molar Ratio	$\leq$ 106	188
Mean Total Ammonia (µg/L)	$\leq$ 16.2	5.8
Mean Chlorophyll *a* (Chl *a*) (µg/L)	$\geq$ 0.17	0.48
Diaptomus:*Cyclops* Density Ratio	$\geq$ 0.01	0.01
Mean Copepod Biomass (mg/m^3)	$\geq$ 0.40	2.50
Bosmina:*Daphnia* Density Ratio	$\geq$ 0.17	8.73
Mean Cladoceran Biomass (mg/m^3)	$\geq$ 2.20	3.12
Cladoceran (*Bosmina*) average size (mm)	> 0.40	0.44
Stocking		
Sockeye	NA	254,030
Commercial Harvest from the FBSHA [b]		
Chinook	NA	1
Sockeye	NA	6,508
Coho	NA	0
Pink	NA	3
Chum	NA	1

Note: NA = Not a specified threshold criteria in the HLMP.

[b] Foul Bay Special Harvest Area – statistical area 251-41.

Table 2.–Seasonal mean total Kjeldahl nitrogen, nitrate+nitrite, total phosphorus concentrations, and total nitrogen to total phosphorus ratio by weight from the epilimnion of Hidden Lake, 1987, 1990-2009.

Year	Depth (m)	TKN (µg/L N)	No^3+No^2 (µg/L N)	TP (µg/L P)	TN:TP Ratio
1987	1	90.1	82.0	4.2	91
1990	1	101.3	65.9	3.9	94
1991	1	75.2	53.4	4.1	70
1992	1	93.7	64.9	4.0	87
1993	1	102.0	45.7	3.7	88
1994	1	120.3	19.7	4.6	67
1995	1	108.6	39.4	3.8	87
1996	1	92.6	38.9	3.4	85
1997	1	93.0	20.1	3.1	80
1998	1	100.5	13.3	3.1	83
1999	1	92.8	51.3	3.1	104
2000	1	ND	48.2	4.9	–
2001	1	99.5	25.8	5.1	54
2002	1	115.0	24.2	5.5	56
2003	1	102.7	57.1	4.7	75
2004	1	179.8	43.0	8.1	61
2005	1	152.0	37.0	7.7	54
2006	1	234.3	40.4	2.1	290
2007	1	90.0	44.0	2.8	106
2008	1	57.0	46.7	4.0	57
2009	1	152.5	59.9	2.5	188
Mean (1987–1991)	1	88.9	67.1	4.1	85
Mean (1992–2008)	1	114.6	38.8	4.3	90

Note: TKN = Total Kjeldahl nitrogen.
No^3+No^2 = Nitrate + nitrite.
TP = Total phosphorus.
TN:TP = Total nitrogen to total phosphorus ratio by weight.
ND = No data.

Table 3.–Summary of seasonal mean nutrient and algal pigment concentrations by station and depth for Hidden Lake, 1987, 1990–2009.

		Total Phosphorus		Total Filterable-P		Filterable Reactive-P		Total Kjeldahl Nitrogen		Ammonia		Nitrate+Nitrite		Chlorophyll *a*	
Year	Depth (m)	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD
1987	1	4.2	0.4	2.2	0.7	0.9	0.1	90.1	2.4	4.3	3.1	82.0	11.7	0.15	0.0
	25	4.0	1.6	2.9	0.9	1.1	0.2	80.7	11.4	4.6	3.2	90.9	5.7	0.06	0.1
1990	1	3.9	2.2	3.6	3.8	2.1	1.1	101.3	48.7	3.8	4.3	65.9	11.3	0.29	0.0
	29	2.1	1.2	1.4	0.3	1.2	0.2	79.2	34.0	6.1	2.3	88.7	16.4	0.11	0.0
1991	1	4.1	1.9	4.0	3.1	3.4	2.6	75.2	44.5	12.0	4.1	53.4	25.1	0.18	0.1
	30	3.1	0.7	2.5	0.7	1.9	0.8	82.9	19.1	13.6	3.4	70.4	13.7	0.07	0.1
1992	1	4.0	0.4	2.0	0.4	1.8	0.2	93.7	41.0	4.1	2.9	64.9	15.8	0.22	0.1
	27	5.1	3.8	2.5	0.9	2.4	1.1	98.8	34.3	3.7	2.5	74.3	16.0	0.11	0.1
1993	1	3.7	2.6	5.1	6.3	3.0	3.3	102.0	30.9	12.6	11.4	45.7	22.1	0.79	0.4
	42	3.1	1.6	2.4	1.1	1.9	1.1	84.2	23.4	16.2	9.0	90.4	16.1	0.20	0.2
1994	1	4.6	1.7	1.7	0.5	1.2	0.5	120.3	33.3	4.3	2.5	19.7	19.9	1.11	0.3
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.87	0.9
	40	4.3	2.3	1.5	0.5	1.2	0.4	88.2	17.7	7.4	3.8	54.9	3.4	0.08	0.1
1995	1	3.8	2.2	2.2	1.6	1.7	1.2	108.6	24.6	9.7	3.0	39.4	15.8	0.77	0.3
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.70	0.3
	43	3.6	2.2	2.0	0.8	1.3	0.7	91.7	12.9	10.2	1.9	64.2	3.6	0.22	0.2
1996	1	3.4	0.9	3.6	0.4	1.9	0.2	92.6	8.0	3.8	4.6	38.9	13.8	0.51	0.1
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.46	0.1
	42	3.7	1.5	3.6	0.8	1.9	0.4	80.4	7.1	7.2	3.7	72.5	5.1	0.14	0.1
1997	1	3.1	1.4	1.9	0.4	1.6	0.3	93.0	8.8	7.8	8.3	20.1	13.2	0.39	0.1
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.41	0.1
	43	3.3	1.2	2.7	1.1	2.2	1.1	87.7	14.2	15.1	9.5	47.7	3.0	0.12	0.1

-continued-

Table 3.–Page 2 of 2.

		Total Phosphorus		Total Filterable-P		Filterable Reactive-P		Total Kjeldahl Nitrogen		Ammonia		Nitrate+Nitrite		Chlorophyll *a*	
Year	Depth (m)	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD	(µg/L)	SD
1998	1	3.1	1.0	2.4	0.8	1.7	0.9	100.5	11.5	5.5	4.5	13.3	4.8	0.45	0.2
	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.18	0.2
	42	3.2	0.5	2.5	0.8	1.8	0.8	98.2	16.6	6.4	3.8	17.2	5.8	0.38	0.2
1999	1	3.1	0.4	1.7	0.3	1.2	0.3	92.8	8.9	10.7	1.6	51.3	20.7	0.17	0.1
	42	3.2	0.3	1.9	0.2	1.3	0.3	81.0	7.3	15.1	4.4	73.0	10.3	0.09	0.1
2000	1	4.9	4.0	2.8	1.3	1.4	1.4	ND	ND	11.9	10.3	48.2	15.1	1.03	1.2
2001	1	5.1	1.8	4.1	2.6	3.3	3.7	99.5	19.7	5.5	4.4	25.8	12.3	0.64	0.2
2002	1	5.5	4.0	2.0	0.7	2.0	1.3	115	26.9	6.2	2.3	24.2	15.6	0.60	0.1
2003	1	4.7	2.3	1.6	1.0	3.2	0.6	102.7	21.3	3.7	3.2	57.1	18.6	0.70	0.2
2004	1	8.2	8.3	4.5	4.6	3.1	1.4	179.8	120.6	7.4	2.0	43.0	22.1	0.48	0.3
2005	1	7.7	2.3	5.0	1.2	3.8	0.4	152.0	22.0	4.7	2.3	37.1	22.2	0.48	0.2
2006	1	2.1	1.2	1.4	0.8	2.2	1.2	234.3	276.4	8.4	2.8	40.4	17.8	0.72	0.4
2007	1	2.8	0.4	1.3	0.4	1.3	0.3	90.0	20.3	5.5	0.2	44.0	14.0	0.72	0.2
2008	1	4.0	1.8	1.6	0.3	2.2	0.9	57.0	32.6	5.7	1.9	46.7	18.6	0.64	0.3
2009	1	2.5	0.5	0.7	0.2	3.6	1.7	152.5	19.1	5.8	2.3	59.9	21.1	0.48	0.2
mean (1987–1991)	1	4.1	1.5	3.2	2.6	2.1	1.3	88.9	31.9	6.7	3.8	67.1	16.0	0.21	0.0
mean (1992–2008)	1	4.3	2.2	2.6	1.4	2.1	1.1	114.6	44.2	6.9	4.0	38.8	16.6	0.61	0.3

Note: SD = Standard deviation
ND = No data

Table 4.–Summary of the Hidden Lake weighted mean density and biomass of Cladocerans and Copepods and their density ratio, 1987, 1990–2009.

	Cladoceran		Copepod		Total		Cladoceran to Copepod ratios [a]	
Year	Density ($no./m^3$)	Biomass (mg/m^3)	Density ($no./m^3$)	Biomass (mg/m^3)	Density ($no./m^3$)	Biomass (mg/m^3)	Abundance Ratio	Biomass Ratio
1987	2,056	7.53	3,820	9.32	5,876	16.85	0.54 :1	0.45 :1
1990	1,581	5.24	4,193	12.58	5,774	17.82	0.38 :1	0.29 :1
1991	818	3.69	3,526	9.04	4,344	12.73	0.23 :1	0.29 :1
1992	873	3.79	3,130	6.26	4,003	10.05	0.28 :1	0.38 :1
1993	829	2.74	309	0.67	1,138	3.41	2.68 :1	0.80 :1
1994	1,162	5.05	153	0.44	1,315	5.49	7.59 :1	0.92 :1
1995	1,215	4.75	1,171	2.87	2,386	7.62	1.04 :1	0.62 :1
1996	692	2.21	2,170	4.93	2,862	7.14	0.32 :1	0.31 :1
1997	683	3.84	373	0.78	1,056	4.62	1.83 :1	0.83 :1
1998	1,281	4.13	1,110	2.68	2,391	6.81	1.15 :1	0.61 :1
1999	618	2.85	3,357	6.00	3,975	8.85	0.18 :1	0.32 :1
2000	728	2.48	601	1.05	1,329	3.53	1.21 :1	0.70 :1
2001	1,156	2.73	339	1.07	1,495	3.80	3.41 :1	0.72 :1
2002	3,282	9.54	1,452	2.50	4,734	12.04	2.26 :1	0.79 :1
2003	1,631	5.67	8,517	12.28	10,148	17.95	0.19 :1	0.32 :1
2004	1,701	7.36	3,564	5.63	5,265	12.99	0.48 :1	0.57 :1
2005	1,165	3.06	6,221	6.89	7,386	9.95	0.19 :1	0.31 :1
2006	1,317	6.05	1,280	2.96	2,597	9.01	1.03 :1	0.67 :1
2007	869	1.71	3,142	4.78	4,011	6.49	0.28 :1	0.26 :1
2008	1,631	5.99	797	2.08	2,428	8.07	2.05 :1	0.74 :1
2009	1,620	3.12	1,234	2.50	2,854	5.62	1.31 :1	0.56 :1
mean (1987–1991)	1,485	5.49	3,846	10.31	5,331	15.80	0.39 :1	0.35 :1
mean (1992–2008)	1,225	4.35	2,217	3.76	3,442	8.11	1.54 :1	0.58 :1

[a] Values are based on predominate species only.

Table 5.–Hidden Lake weighted mean Copepod density and biomass by species and the *Diaptomus* to *Cyclops* density ratio, 1987, 1990–2009.

Year	# Sample Events	*Diaptomus* Density (no./m^3)	*Diaptomus* Biomass (mg/m^3)	*Cyclops* Density (no./m^3)	*Cyclops* Biomass (mg/m^3)	Totals Density (no./m^3)	Totals Biomass (mg/m^3)	*Diaptomus* to *Cyclops* Ratio [a]
1987	3	803	2.40	3,017	6.92	3,820	9.32	0.27 :1
1990	4	1,106	5.05	3,087	7.53	4,193	12.58	0.36 :1
1991	5	782	2.70	2,744	6.34	3,526	9.04	0.28 :1
1992	6	804	1.66	2,326	4.60	3,130	6.26	0.35 :1
1993	6	0	0.00	309	0.67	309	0.67	0.00 :1
1994	7	0	0.00	153	0.44	153	0.44	0.00 :1
1995	7	0	0.00	1,171	2.87	1,171	2.87	0.00 :1
1996	6	1	0.00	2,169	4.93	2,170	4.93	0.00 :1
1997	6	1	0.00	372	0.78	373	0.78	0.00 :1
1998	5	0	0.00	1,110	2.68	1,110	2.68	0.00 :1
1999	5	0	0.00	3,357	6.00	3,357	6.00	0.00 :1
2000	5	0	0.00	601	1.05	601	1.05	0.00 :1
2001	5	0	0.00	339	1.07	339	1.07	0.00 :1
2002	5	0	0.00	1,452	2.50	1,452	2.50	0.00 :1
2003	4	6	0.01	8,511	12.27	8,517	12.28	0.00 :1
2004	4	70	0.33	3,494	5.30	3,564	5.63	0.02 :1
2005	4	57	0.08	6,164	6.81	6,221	6.89	0.01 :1
2006	5	56	0.06	1,224	2.90	1,280	2.96	0.05 :1
2007	4	7	0.02	3,135	4.76	3,142	4.78	0.00 :1
2008	4	12	0.04	785	2.04	797	2.08	0.02 :1
2009	4	8	0.05	1,226	2.45	1,234	2.50	0.01 :1
mean (1987–1991)		897	3.38	2,949	6.93	3,846	10.31	0.30 :1
mean (1992–2008)		60	0.13	2,157	3.63	2,217	3.76	0.03 :1
mean (1993–2008)		13	0.03	2,147	3.57	2,160	3.60	0.01 :1

[a] Values are based on mean density.

Table 6.–Summary of the Hidden Lake weighted mean density and biomass of Cladocerans by species and the *Bosmina* to *Daphnia* density ratio, 1987, 1990–2009.

	#	*Bosmina*		*Daphnia*		*Holopedium*		Totals		*Bosmina* to
	Sample	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	*Daphnia*
Year	Events	(no./m^3)	(mg/m^3)	(no./m^3)	(mg/m^3)	(no./m^3)	(mg/m^3)	(no./m^3)	(mg/m^3)	Ratio [a]
1987	3	1,059	2.73	788	2.59	209	2.21	2,056	7.53	1.34 :1
1990	4	1,028	3.01	502	1.70	51	0.53	1,581	5.24	2.05 :1
1991	5	529	1.46	177	0.46	112	1.77	818	3.69	2.99 :1
1992	6	614	1.58	86	0.25	173	1.96	873	3.79	7.14 :1
1993	6	89	0.21	526	0.99	214	1.54	829	2.74	0.17 :1
1994	7	574	1.17	389	1.00	199	2.88	1,162	5.05	1.48 :1
1995	7	764	1.62	203	0.49	248	2.64	1,215	4.75	3.76 :1
1996	6	535	1.09	20	0.03	137	1.09	692	2.21	26.75 :1
1997	6	277	0.45	177	0.28	229	3.11	683	3.84	1.56 :1
1998	5	724	1.30	454	1.50	103	1.33	1,281	4.13	1.59 :1
1999	5	210	0.32	258	0.68	150	1.85	618	2.85	0.81 :1
2000	5	376	0.85	53	0.08	299	1.55	728	2.48	7.09 :1
2001	5	585	1.25	46	0.13	525	1.35	1,156	2.73	12.72 :1
2002	5	1,639	3.74	1,218	3.81	425	1.99	3,282	9.54	1.35 :1
2003	4	878	3.04	437	0.78	316	1.85	1,631	5.67	2.01 :1
2004	4	847	3.68	442	1.25	412	2.43	1,701	7.36	1.92 :1
2005	4	583	1.13	392	0.69	190	1.24	1,165	3.06	1.49 :1
2006	5	505	1.05	182	0.28	630	4.72	1,317	6.05	2.77 :1
2007	4	551	1.07	180	0.27	138	0.37	869	1.71	3.06 :1
2008	4	366	0.78	203	0.34	1,062	4.87	1,631	5.99	1.80 :1
2009	4	262	0.48	30	0.05	1,328	2.59	1,620	3.12	8.73 :1
mean (1987–1991)		872	2.40	489	1.58	124	1.50	1,485	5.49	1.78 :1
mean (1992–2008)		595	1.43	310	0.76	321	2.16	1,225	4.35	4.56 :1

[a] Values are based on mean density.

Table 7.–Seasonal weighted mean lengths (mm) of zooplankton taxa in Hidden Lake, 1987, 1990–2009.

Year	*Diaptomus*	*Cyclops*	*Bosmina*	*Daphnia*	*Holopedium*
1987	0.88	0.81	0.52	0.86	0.97
1990	1.02	0.83	0.55	0.87	0.96
1991	0.93	0.81	0.54	0.77	1.14
1992	0.77	0.76	0.52	0.81	1.00
1993	–[a]	0.79	0.50	0.66	0.83
1994	–[a]	0.90	0.47	0.76	0.92
1995	–[a]	0.83	0.47	0.74	0.84
1996	1.10	0.81	0.47	0.62	0.83
1997	–[a]	0.77	0.42	0.62	0.87
1998	–[a]	0.82	0.44	0.86	0.90
1999	–[a]	0.72	0.40	0.76	0.93
2000	–[a]	0.71	0.49	0.59	0.71
2001	–[a]	0.93	0.48	0.79	0.53
2002	–[a]	0.71	0.49	0.83	0.70
2003	1.15	0.67	0.46	0.70	0.76
2004	1.16	0.69	0.48	0.84	0.75
2005	0.68	0.58	0.46	0.64	0.78
2006	1.17	0.82	0.47	0.61	0.84
2007	0.89	0.67	0.46	0.59	0.55
2008	0.95	0.86	0.47	0.63	0.67
2009	1.15	0.76	0.44	0.60	0.48
mean (1987–1991)	0.94	0.82	0.54	0.83	1.02
mean (1992–2008)	0.98	0.77	0.47	0.71	0.79

[a] *Diaptomus* were not identified in the samples collected.

Table 8.–Sockeye salmon stocking numbers, life stage, size and release date by year into Hidden Lake, 1992–2009.

Year	# Fry	Date/Size [a]	# Fingerling	Date/Size [a]	# Pre-Smolt	Date/Size [a]	Total Stocked
1992					260,000	5-Sep/6.0 g	260,000
1993	448,000	29-Apr/0.25 g	106,600	4-Jun/0.5 g			554,600
1994	250,000	5-May/0.25 g					250,000
1995					98,650	2-Nov/9.5 g	98,650
1996	252,000	14-May/0.4 g			138,800	15-Oct/9.0 g	390,800
1997			287,700	4-Jun/0.6 g	167,500	22-Oct/9.5 g	455,200
1998					340,400	4-Sep/7.0 g	340,400
1999					310,000	6-Oct/9.4 g	310,000
2000	172,000	20-Jun/0.7 g			332,400	24-Aug/5.0 g	504,400
2001			66,500	25-May/0.8 g	249,000	5-Oct/13.5 g	315,500
2002					51,600	2-Oct/11.0 g	51,600
2003					31,006	14-Sep/13.9 g	31,006
2004					70,736	7,8-Oct/8.95 g	70,736
2005			113,679	23-Jun/1.4 g	74,663	3-Oct/11.7 g	188,342
2006	253,100	19-May/0.45 g			168,568	10-Oct/11.76 g	421,668
2007	300,315	17-Jun/0.42 g			199,992	29-Sep/9.56 g	500,307
2008	153,925	9-Jun/0.4 g			199,876	27-28-Sep/7.5 g	353,801
2009	149,300	17-Jun/0.42 g			104,730	2-Oct/9.17 g	254,030
mean (1992–2008)							297,280

Note: Stocking sizes reported from the hatchery were not always reported to the same number of digits.

[a] Fry are released from April to July at up to 200% of emergent size (normally 0.15 to 0.5 g depending on the stock). Fingerling are released from June to September at a size of >200% to <2100% of emergent size (normally 0.3 to 5.25 g depending on the stock). Pre-smolt are released from August to November at a size of >2100% of emergent size but not yet at the physiological stage of smolting (normally 5 to 13 g).

Table 9.–Commercial harvest by species by day in the Foul Bay Special Harvest Area (statistical area 251-41), 2009.

Date	Chinook	Sockeye	Coho	Pink	Chum
9-Jun					
10-Jun					
11-Jun					
14-Jun					
17-Jun					
21-Jun					
24-Jun					
29-Jun					
Total	1	6,508	0	3	1

Note: Blank cells contain confidential data.

Table 10.–Commercial harvest by species by year in the Foul Bay Special Harvest Area (statistical area 251-41), 1995–2009.

Year	Chinook	Sockeye	Coho	Pink	Chum
1995	15	3,1190[a]	0	20	8
1996	6	29,708[a]	15	7	63
1997	0	13,751[a]	0	5	2
1998	17	8,270	0	55	57
1999	12	41,042	0	415	364
2000	5	23,643[a]	0	1	23
2001	104	29,822	0	1,141	53
2002	196	33,444	0	120	1,243
2003	55	51,181	0	80	98
2004	27	19,729	0	0	29
2005	4	7,389[a]	0	0	0
2006	16	1,181[a]	15	525	92
2007	7	703	1	46	149
2008	2	5,715	5	375	126
2009	1	6,508	0	3	1
mean (1995-2008)	33	23,738	3	199	165

[a] Historical harvest numbers differ from previous reports due to fish ticket editing.

Table 11.–Estimated age composition of adult sockeye salmon harvest from Foul Bay Special Harvest Area (statistical area 251-41), 1995–2005, 2009.

Year	Sample Size		Ages 1.1	0.2	0.3	1.2	2.1	1.3	2.2	3.1	1.4	2.3	3.2	2.4	Total [a]
1995[b]	485	Numbers	1,035	0	34	29,271	0	494	34	0	0	322	0	0	31,190
		Percent	3	0	0	94	0	2	0	0	0	1	0	0	100
1996[b]	537	Numbers	297	0	0	9,328	119	18,360	1,485	0	0	119	0	0	29,708
		Percent	1	0	0	31	0	62	5	0	0	0	0	0	100
1997[b]	562	Numbers	578	0	0	6,078	14	6,119	481	14	28	344	41	28	13,751
		Percent	4	0	0	44	0	45	4	0	0	3	0	0	100
1998	646	Numbers	2,447	0	0	3,949	365	1,054	397	0	0	58	0	0	8,270
		Percent	30	0	0	48	4	13	5	0	0	1	0	0	100
1999	603	Numbers	68	0	0	36,414	0	1,906	2,450	0	0	204	0	0	41,042
		Percent	0	0	0	89	0	5	6	0	0	1	0	0	100
2000[b]	733	Numbers	331	0	0	14,777	0	7,069	969	0	24	473	0	0	23,643
		Percent	1	0	0	63	0	30	4	0	0	2	0	0	100
2001	551	Numbers	517	0	0	8,602	0	20,206	123	0	0	374	0	0	29,822
		Percent	2	0	0	29	0	68	0	0	0	1	0	0	100
2002	903	Numbers	2,361	37	0	22,160	84	8,588	214	0	0	0	0	0	33,444
		Percent	7	0	0	66	0	26	1	0	0	0	0	0	100
2003	669	Numbers	44	0	0	40,221	0	9,205	867	0	0	844	0	0	51,181
		Percent	0	0	0	79	0	18	2	0	0	2	0	0	100
2004	411	Numbers	0	0	0	9,949	0	7,314	2,343	0	0	123	0	0	19,729
		Percent	0	0	0	50	0	37	12	0	0	1	0	0	100
2005[b]	232	Numbers	0	0	0	96	0	5,478	96	0	0	1,720	0	0	7,389
		Percent	0	0	0	1	0	74	1	0	0	23	0	0	100

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Year	Sample Size		Ages 1.1	0.2	0.3	1.2	2.1	1.3	2.2	3.1	1.4	2.3	3.2	2.4	Total [a]
2009	328	Numbers	655	0	0	2,321	20	2,758	278	0	0	476	0	0	6,508
		Percent	10	0	0	36	0	42	4	0	0	7	0	0	100
mean	576	Numbers	7,678	37	34	180,845	581	85,793	9,460	14	51	4,580	41	28	289,169
(1995-2005)		Percent	3	0	0	63	0	30	3	0	0	2	0	0	100

Note: Includes fish harvested in the Foul Bay SHA (reported in statistical area 251-41) only. Due to difficulties allocating harvest in statistical area 251-40 FBSHA harvest may be under reported.

[a] Due to rounding the age composition numbers and total column may differ.

[b] Historical harvest numbers have changed slightly due to database editing. Age data from the 1994 harvest is not included in the table.

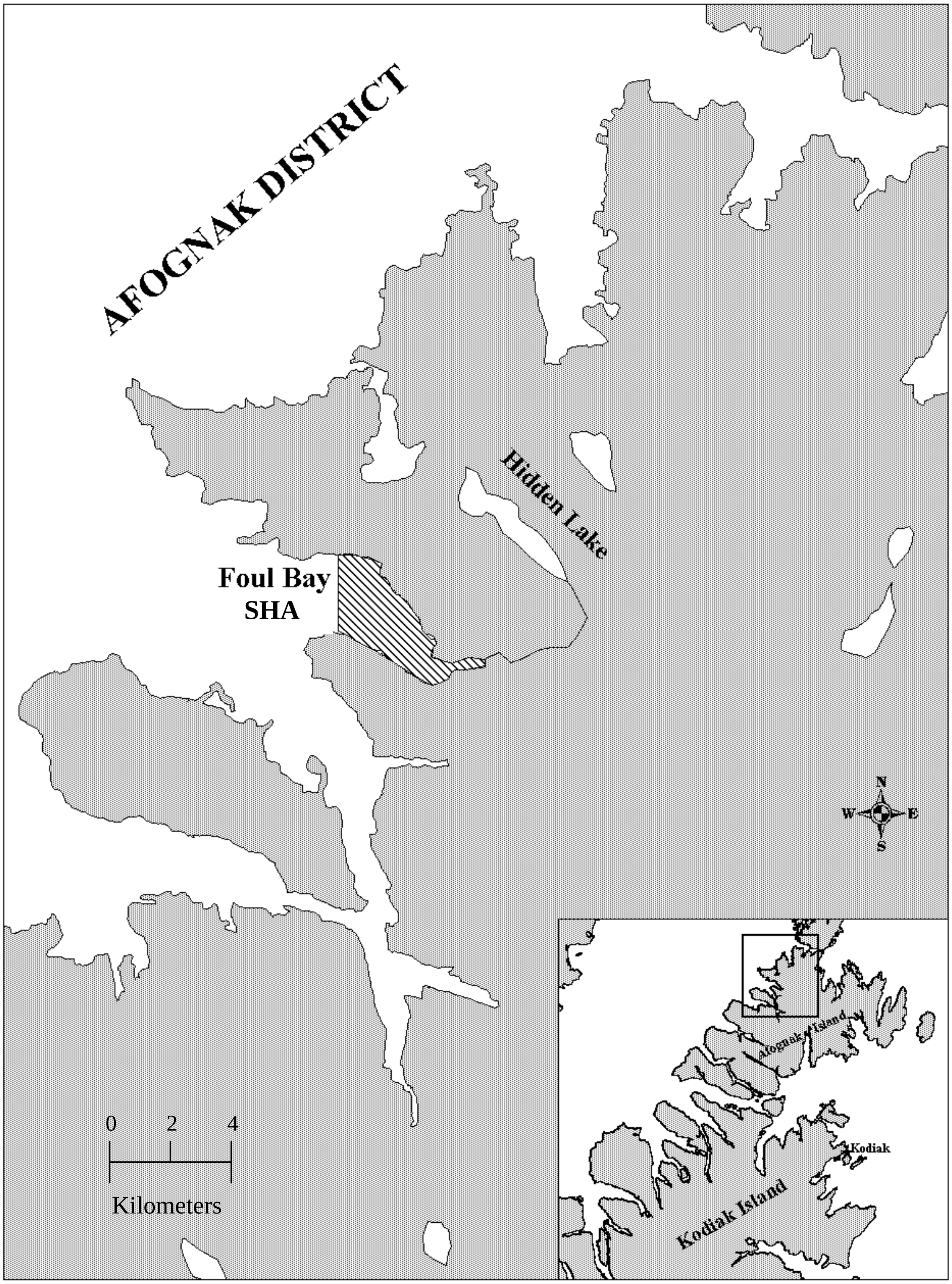

Figure 1.–Location of Hidden Lake and the Foul Bay Special Harvest Area on Afognak Island.

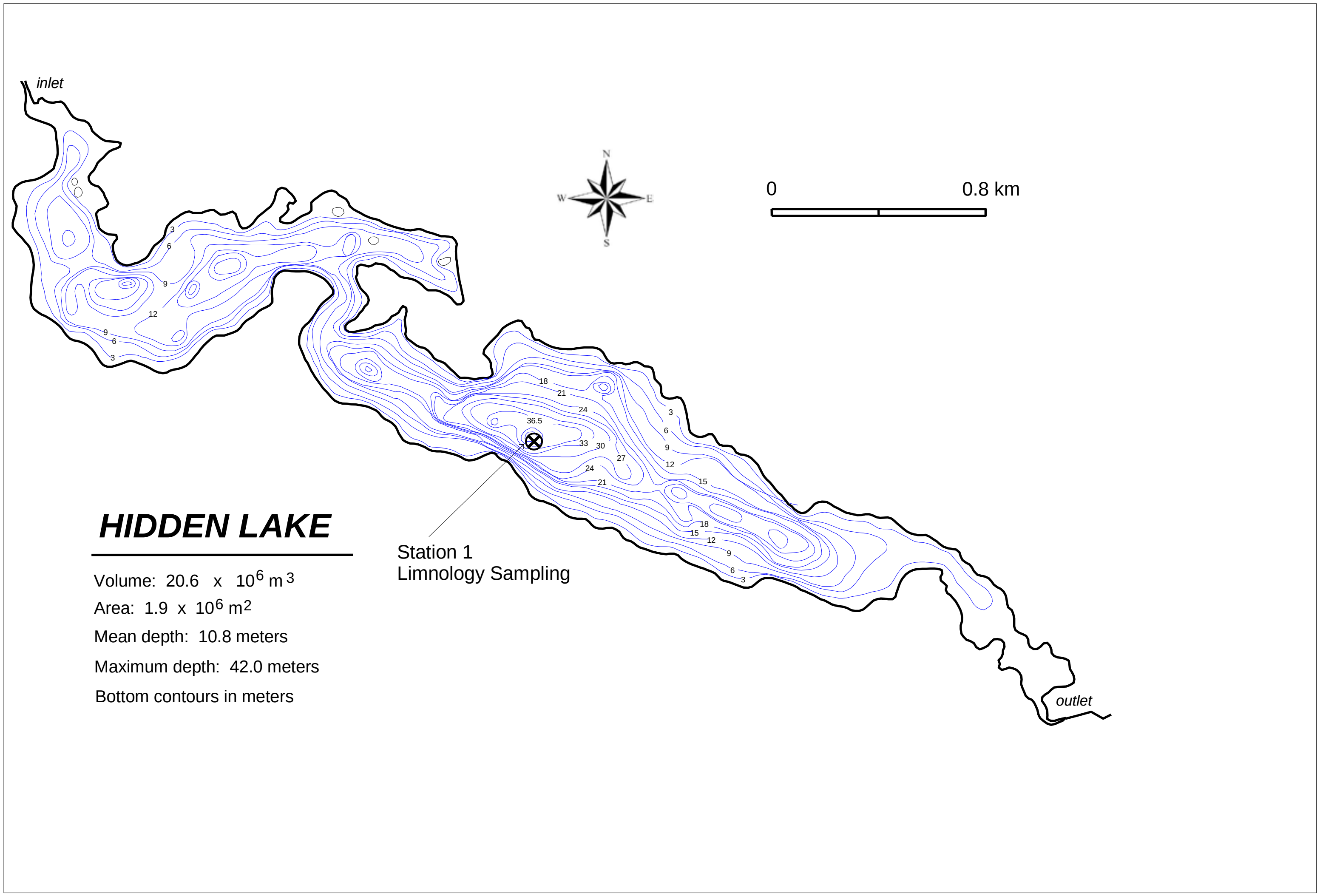

Figure 2.–Morphometric map showing the limnology sampling station on Hidden Lake.

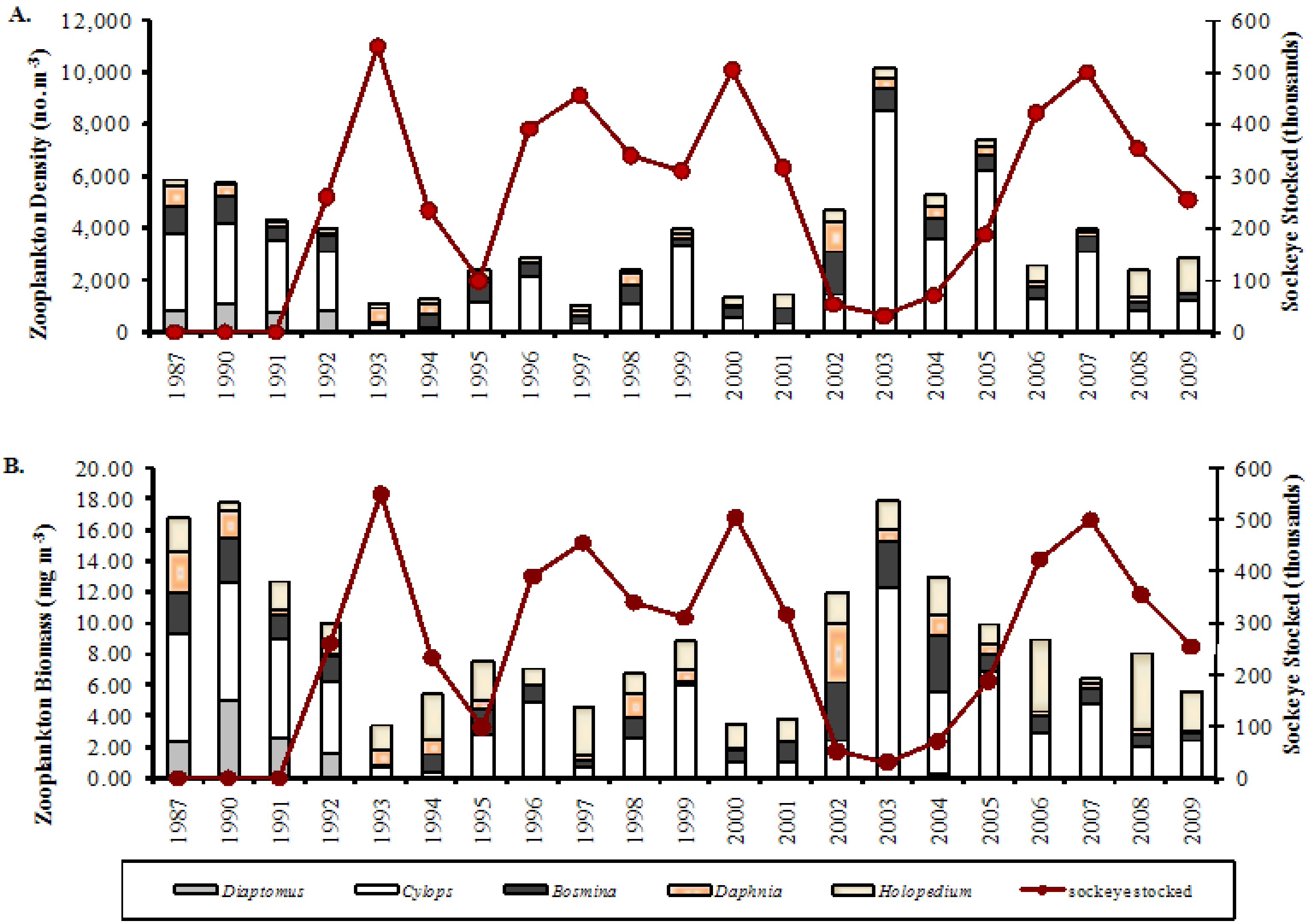

Figure 3.–Zooplankton density (A) and biomass (B) compared to sockeye salmon stocking levels for Hidden Lake, 1987, 1990–2009.

APPENDIX A. HISTORICAL LIMNOLOGICAL DATA

Appendix A1.–Limnological sampling stations and total samples collected at Hidden Lake, 1987–2009.

Year	Sampling Stations	Total Samples
1987	1	3
1989	1	1
1990	1	4
1991	1	5
1992	1	6
1993	1	6
1994	1, 2	7
1995	1, 2	7
1996	1, 2	6
1997	1, 2	6
1998	1	5
1999	1	5
2000	1	5
2001	1	5
2002	1	5
2003	1	4
2004	1	4
2005	1	4
2006	1	5
2007	1	4
2008	1	5
2009	1	4

Appendix A2.–Summary of seasonal mean water chemistry parameters by station and depth for Hidden Lake, 1987, 1990–2009.

Year	Station	Depth (m)	Specific Conductivity (umhos/cm)	SD	pH (Units)	SD	Alkalinity (mg/L)	SD	Turbidity (NTU)	SD	Color (Pt units)	SD	Calcium (mg/L)	SD	Magnesium (mg/L)	SD	Iron (ug/L)	SD
1987	1	1	41.3	1.2	6.7	0.2	7.5	1.5	0.5	0.4	9.7	2.1	2.7	0.1	0.4	0.2	83.3	98.5
	1	25	42.0	1.7	6.7	0.2	6.7	1.5	0.6	0.4	11.7	2.5	2.8	0.2	0.6	0.2	94.3	86.6
1990	1	1	62.8	2.0	6.9	0.2	8.2	1.3	0.7	0.3	17.0	7.6	3.7	0.6	1.1	0.6	52.0	16.0
	1	29	66.3	3.1	6.7	0.2	8.5	0.9	0.5	0.1	13.0	2.0	3.9	0.5	1.1	0.3	39.8	9.3
1991	1	1	45.0	8.2	6.8	0.1	9.0	1.0	0.7	0.4	17.4	6.3	3.3	0.6	0.8	0.1	33.8	14.6
	1	30	46.2	8.3	6.8	0.2	10.3	1.9	0.5	0.2	15.6	3.0	3.3	0.5	0.9	0.3	37.8	10.7
1992	1	1	47.0	1.4	6.6	0.1	8.5	1.5	0.7	0.5	10.7	0.8	4.0	0.4	0.8	0.5	33.2	10.4
	1	27	47.3	1.0	6.5	0.2	10.6	5.3	0.8	0.7	12.0	1.1	3.5	0.8	1.0	0.6	68.7	88.7
1993	1	1	50.5	3.9	6.6	0.2	9.1	1.4	0.8	0.4	10.2	1.6	3.8	0.4	0.9	0.3	34.8	9.3
	1	42	50.3	3.1	6.5	0.2	8.8	1.0	0.6	0.5	10.7	2.3	4.0	0.2	0.9	0.3	54.0	27.2
1994	1	1	47.9	2.9	6.5	0.2	7.2	0.6	0.7	0.3	11.6	1.5	3.2	0.5	1.0	0.3	56.2	22.7
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	40	46.6	1.3	6.3	0.3	7.1	0.7	0.5	0.3	12.6	1.0	3.0	0.1	0.9	0.3	46.8	17.5
1995	1	1	50.0	4.2	6.4	0.1	8.7	1.5	0.9	0.9	15.3	5.7	3.0	0.5	1.0	0.6	78.6	104.4
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	43	50.3	1.4	6.2	0.1	7.3	0.2	0.4	0.2	12.3	1.8	2.8	0.3	0.8	0.5	38.9	7.4
1996	1	1	50.3	1.6	6.6	0.2	8.2	0.7	0.8	0.7	14.8	1.9	2.9	0.3	0.9	0.4	36.8	9.5
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	42	51.5	1.6	6.3	0.1	7.4	0.3	0.5	0.3	16.5	2.1	2.7	0.1	0.9	0.4	22.8	7.5
1997	1	1	49.2	1.2	6.9	0.1	9.9	1.5	0.4	0.1	12.0	1.7	2.9	0.2	0.8	0.3	29.3	9.3
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	43	50.5	0.8	6.7	0.1	9.6	0.7	0.4	0.1	14.3	1.9	2.8	0.1	0.8	0.3	28.3	8.4
1998	1	1	43.3	1.0	6.9	0.0	9.8	1.7	0.9	0.5	13.3	1.0	3.0	0.5	0.7	0.2	24.5	6.6
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	42	44.8	1.5	6.8	0.1	9.3	0.5	0.9	0.4	13.8	0.4	3.0	0.5	0.7	0.2	26.1	3.5
1999	1	1	49.4	1.5	6.8	0.3	8.9	0.7	0.6	0.6	11.6	1.1	3.3	0.3	1.0	0.2	41.8	12.5
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	42	50.2	0.8	6.6	0.2	8.4	0.5	0.5	0.3	11.4	0.5	3.4	0.1	1.0	0.2	40.4	8.0

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Year	Station	Depth	Specific Conductivity		pH		Alkalinity		Turbidity		Color		Calcium		Magnesium		Iron	
		(m)	(umhos/cm)	SD	(Units)	SD	(mg/L)	SD	(NTU)	SD	(Pt units)	SD	(mg/L)	SD	(mg/L)	SD	(ug/L)	SD
2000	1	1	ND	ND	7.3	0.2	7.2	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2001	1	1	ND	ND	7.2	0.1	8.1	1.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2002	1	1	ND	ND	6.8	0.1	8.1	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2003	1	1	ND	ND	6.7	0.1	7.6	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2004	1	1	ND	ND	6.9	0.2	8.8	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2005	1	1	ND	ND	6.7	0.1	7.8	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2006	1	1	ND	ND	6.7	0.1	7.5	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2007	1	1	ND	ND	6.7	0.1	8.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2008	1	1	ND	ND	6.7	0.1	8.2	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2009	1	1	ND	ND	7.0	0.2	9.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND = No data.

Appendix A3.–Summary of seasonal mean nutrient and algal pigment concentrations by station and depth for Hidden Lake, 1987, 1990–2009.

Year	Station	Depth (m)	Total-P (ug/L P)	SD	Total Filterable-P (ug/L P)	SD	Filterable Reactive-P (ug/L P)	SD	Total Kjeldahl Nitrogen (ug/L N)	SD	Ammonia (ug/L N)	SD	Nitrate+ Nitrite (ug/L N)	SD	Reactive Silicon (ug/L Si)	SD	Chlorophyll *a* (ug/L)	SD
1987	1	1	4.2	0.4	2.2	0.7	0.9	0.1	90.1	2.4	4.3	3.1	82.0	11.7	1840.0	436.6	0.15	0.0
	1	25	4.0	1.6	2.9	0.9	1.1	0.2	80.7	11.4	4.6	3.2	90.9	5.7	1875.0	454.7	0.06	0.1
1990	1	1	3.9	2.2	3.6	3.8	2.1	1.1	101.3	48.7	3.8	4.3	65.9	11.3	1906.8	318.5	0.29	0.0
	1	29	2.1	1.2	1.4	0.3	1.2	0.2	79.2	34.0	6.1	2.3	88.7	16.4	1956.5	172.9	0.11	0.0
1991	1	1	4.1	1.9	4.0	3.1	3.4	2.6	75.2	44.5	12.0	4.1	53.4	25.1	1727.4	83.1	0.18	0.1
	1	30	3.1	0.7	2.5	0.7	1.9	0.8	82.9	19.1	13.6	3.4	70.4	13.7	1733.8	205.8	0.07	0.1
1992	1	1	4.0	0.4	2.0	0.4	1.8	0.2	93.7	41.0	4.1	2.9	64.9	15.8	1746.5	74.0	0.22	0.1
	1	27	5.1	3.8	2.5	0.9	2.4	1.1	98.8	34.3	3.7	2.5	74.3	16.0	1806.0	99.2	0.11	0.1
1993	1	1	3.7	2.6	5.1	6.3	3.0	3.3	102.0	30.9	12.6	11.4	45.7	22.1	1721.7	133.1	0.79	0.4
	1	42	3.1	1.6	2.4	1.1	1.9	1.1	84.2	23.4	16.2	9.0	90.4	16.1	1896.0	82.5	0.20	0.2
1994	1	1	4.6	1.7	1.7	0.5	1.2	0.5	120.3	33.3	4.3	2.5	19.7	19.9	1651.6	101.5	1.11	0.3
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.87	0.9
	1	40	4.3	2.3	1.5	0.5	1.2	0.4	88.2	17.7	7.4	3.8	54.9	3.4	1813.9	82.5	0.08	0.1
1995	1	1	3.8	2.2	2.2	1.6	1.7	1.2	108.6	24.6	9.7	3.0	39.4	15.8	1893.9	248.5	0.77	0.3
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.70	0.3
	1	43	3.6	2.2	2.0	0.8	1.3	0.7	91.7	12.9	10.2	1.9	64.2	3.6	1934.7	112.9	0.22	0.2
1996	1	1	3.4	0.9	3.6	0.4	1.9	0.2	92.6	8.0	3.8	4.6	38.9	13.8	1650.3	85.1	0.51	0.1
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.46	0.1
	1	42	3.7	1.5	3.6	0.8	1.9	0.4	80.4	7.1	7.2	3.7	72.5	5.1	1754.7	30.3	0.14	0.1
1997	1	1	3.1	1.4	1.9	0.4	1.6	0.3	93.0	8.8	7.8	8.3	20.1	13.2	1792.5	136.3	0.39	0.1
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.41	0.1
	1	43	3.3	1.2	2.7	1.1	2.2	1.1	87.7	14.2	15.1	9.5	47.7	3.0	1908.8	136.2	0.12	0.1
1998	1	1	3.1	1.0	2.4	0.8	1.7	0.9	100.5	11.5	5.5	4.5	13.3	4.8	1651.0	227.2	0.45	0.2
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.18	0.2
	1	42	3.2	0.5	2.5	0.8	1.8	0.8	98.2	16.6	6.4	3.8	17.2	5.8	1627.5	214.0	0.38	0.2
1999	1	1	3.1	0.4	1.7	0.3	1.2	0.3	92.8	8.9	10.7	1.6	51.3	20.7	1857.0	46.3	0.17	0.1
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	42	3.2	0.3	1.9	0.2	1.3	0.3	81.0	7.3	15.1	4.4	73.0	10.3	1997.6	83.8	0.09	0.1

-continued-

Year	Station	Depth (m)	Total-P (ug/L P)	SD	Total Filterable-P (ug/L P)	SD	Filterable Reactive-P (ug/L P)	SD	Total Kjel-dahl Nitrogen (ug/L N)	SD	Ammonia (ug/L N)	SD	Nitrate+ Nitrite (ug/L N)	SD	Reactive Silicon (ug/L Si)	SD	Chlorophyll *a* (ug/L)	SD
2000	1	1	4.9	4.0	2.8	1.3	1.4	1.1	<60	ND	11.9	10.3	83.1	31.2	ND	ND	1.03	1.2
2001	1	1	5.1	1.8	4.1	2.6	3.3	3.7	99.5	19.7	5.5	4.4	25.8	12.3	ND	ND	0.64	0.2
2002	1	1	5.5	4.0	2.0	0.7	2.0	1.3	115.0	26.9	6.2	2.3	24.2	15.6	ND	ND	0.60	0.1
2003	1	1	4.7	2.3	1.6	1.0	3.2	0.6	102.7	21.3	3.7	3.2	57.1	18.6	ND	ND	0.70	0.2
2004	1	1	8.2	8.3	4.5	4.6	3.1	1.4	179.8	120.6	7.4	2.0	43.0	22.1	ND	ND	0.48	0.3
2005	1	1	7.7	2.3	5.0	1.2	3.8	0.4	152.0	22.0	4.7	2.3	37.1	22.2	ND	ND	0.48	0.2
2006	1	1	2.1	1.2	1.4	0.8	2.2	1.2	234.3	276.4	8.4	2.8	40.4	17.8	ND	ND	0.72	0.4
2007	1	1	2.8	0.4	1.3	0.4	1.3	0.3	90.0	20.3	5.5	0.2	44.0	14.0	ND	ND	0.72	0.2
2008	1	1	4.0	1.8	1.6	0.3	2.2	0.9	57.0	32.6	5.7	1.9	46.7	18.6	ND	ND	0.64	0.3
2009	1	1	2.5	0.5	0.7	0.2	3.6	1.7	152.5	19.1	5.8	2.3	59.9	21.1	ND	ND	0.48	0.2

Note: ND = No data.

Appendix A4.–Weighted mean zooplankton density (no./m^2) and biomass (mg/m^2) by species (station 1) for Hidden Lake, 1987–2009.

Year	# sample events	Epischura			Diaptomus			Cyclops			Bosmina			Daphnia			Holopedium		
		Density (no/m^2)	Biomass (mg/m^2)	Size mm	Density (no/m^2)	Biomass (mg/m^2)	Size mm	Density (no/m^2)	Biomass (mg/m^2)	Size mm	Density (no/m^2)	Biomass (mg/m^2)	Size mm	Density (no/m^2)	Biomass (mg/m^2)	Size mm	Density (no/m^2)	Biomass (mg/m^2)	Size mm
1987	3	204	4	1.74	24,080	72	0.88	90,499	208	0.81	31,766	82	0.52	23,629	78	0.86	6,281	66	0.97
1989	1	2,654	44	1.58	91,826	259	0.98	107,219	203	0.74	91,826	226	0.51	16,985	76	0.99	4,246	38	0.91
1990	4	133	4	1.92	33,174	152	1.02	92,622	226	0.83	30,852	90	0.55	15,061	51	0.87	1,526	16	0.96
1991	5	411	7	1.60	23,447	81	0.93	82,307	190	0.81	15,864	44	0.54	5,320	14	0.77	3,372	53	1.14
1992	6	288	3	1.37	17,693	37	0.77	51,177	101	0.76	13,498	35	0.52	1,894	5	0.81	3,813	43	1.00
1993	6	1,561	11	1.17	0	0	-	12,062	26	0.79	3,463	8	0.50	20,510	39	0.66	8,364	60	0.83
1994	7	2,781	38	1.48	0	0	-	6,104	18	0.90	22,943	47	0.47	15,543	40	0.76	7,635	73	0.92
1995	7	1,926	7	0.91	0	0	-	46,846	115	0.83	30,553	65	0.47	8,104	19	0.74	9,912	75	0.84
1996	6	3,556	12	0.91	35	0	1.10	88,924	202	0.81	21,939	45	0.47	832	1	0.62	5,609	41	0.83
1997	6	1,203	12	1.34	35	0	-	15,262	32	0.77	11,366	18	0.42	7,244	12	0.62	9,404	76	0.87
1998	5	1,316	9	1.16	0	0	-	45,527	110	0.82	29,667	53	0.44	18,605	62	0.86	4,242	38	0.90
1999	5	1,656	17	1.33	0	0	-	137,626	246	0.72	8,630	13	0.40	10,576	28	0.76	6,136	60	0.93
2000	5	1,911	13	1.15	0	0	-	26,285	46	0.71	16,199	37	0.49	2,284	3	0.59	13,188	69	0.71
2001	5	7,020	29	0.98	0	0	-	12,399	39	0.93	20,459	44	0.48	1,598	4	0.79	19,421	49	0.53
2002	5	7,166	48	1.15	0	0		53,649	94	0.71	63,442	145	0.49	48,301	152	0.83	16,122	76	0.70
2003	4	398	1	0.75	199	1	1.15	338,575	519	0.67	34,833	68	0.46	17,516	39	0.71	12,739	74	0.76
2004	4	1,194	15	1.45	2,787	18	1.16	140,300	230	0.69	33,506	74	0.48	17,755	59	0.84	16,136	95	0.75
2005	4	2,389	2	0.55	2,389	3	0.68	260,801	289	0.58	24,761	48	0.46	16,534	29	0.64	8,015	52	0.78
2006	5	1,932	16	1.23	584	2	0.93	45,679	109	0.82	21,476	45	0.47	7,622	12	0.61	24,490	185	0.84
2007	4	1,128	2	0.75	265	1	0.88	109,342	167	0.67	20,303	40	0.46	6,701	10	0.59	4,843	13	0.55
2008	5	658	13	1.67	425	2	0.95	28,583	75	0.86	13,445	29	0.47	7,282	12	0.63	38,954	180	0.68
2009	4	66	0	1.19	265	2	1.15	42,529	85	0.76	9,156	17	0.44	1,062	2	0.60	45,249	88	0.48
mean (1987-2008)	5	1,889	14	1.24	8,964	29	0.97	83,378	151	0.77	25,907	58	0.48	12,316	34	0.73	12,259	69	0.81

Appendix A5.–Temperatures (°C) measured at the 1-meter and near bottom strata in the Spring, (May-June), Summer (July-August), and Fall (September-October) for Hidden Lake, 1990–2009.

	Spring		Summer		Fall	
Year	Surface	Bottom	Surface	Bottom	Surface	Bottom
1990	7.0	5.8	14.0	6.0	8.0	8.0
1991	0.5	0.0	14.6	5.4	8.5	6.0
1992	7.7	5.0	14.8	6.0	6.8	6.3
1993	11.0	4.8	16.0	5.3	9.5	5.5
1994	8.3	4.5	15.7	5.1	10.7	5.7
1995	7.6	4.6	14.2	5.6	12.3	8.0
1996	9.5	4.7	13.5	5.5	10.5	5.7
1997	11.4	4.2	16.9	5.0	10.6	5.0
1998	8.9	6.2	15.6	6.9	10.4	7.0
1999	5.7	4.1	13.9	5.8	10.5	6.0
2000	5.4	4.2	14.0	5.2	9.6	5.5
2001	9.5	4.6	15.8	5.4	11.8	5.4
2002	8.9	4.0	14.6	4.7	11.0	4.8
2003	9.2	5.2	17.7	6.1	10.6	6.3
2004	10.2	4.9	17.9	6.2	10.1	6.5
2005	8.2	4.4	16.9	5.3	12.6	5.4
2006	7.1	4.5	14.0	5.3	11.6	5.5
2007	8.3	4.8	14.3	5.4	10.8	5.7
2008	4.5	4.0	13.2	5.5	10.8	5.7
2009	7.8	4.4	13.7	5.5	11.0	5.6

APPENDIX B. JUVENILE AGE, LENGTH, WEIGHT, AND CONDITION, COHO STOCKING, AND HYDROACOUSTICS

Appendix B1.–Mean age, length, weight, and condition coefficient from sockeye salmon smolt collected from Hidden Creek, 1993–2001.

				Age-1					Age-2				
Year	Statistical Weeks	Dates Collected	Number Sampled	no.	%	Mean Length (mm)	Mean Weight (g)	Condition Factor (K)	no.	%	Mean Length (mm)	Mean Weight (g)	Condition Factor (K)
1993	21	May 17-23	324	324	100.0	100.5	8.5	0.83	0	0.0%	—	—	—
1994	24-27	June 7-July 4	218	214	98.2	122.9	16.2	0.87	4	1.8%	145.0	29.1	0.92
1995	23-26	May 31-June 27	153	148	96.7	124.5	20.5	1.00	5	3.3%	164.3	45.8	1.02
1996	23-25	May 31-June 20	440	426	96.8	125.3	18.4	0.94	14	3.2%	159.5	41.6	0.95
1997	23-26	May 31-June 27	442	439	99.3	109.2	11.4	0.87	3	0.7%	120.0	14.7	0.78
1998	22-26	May 24-June 27	462	455	98.5	111.1	12.3	0.89	7	1.5%	140.0	24.1	0.87
1999	23-26	May 31-June 27	262	262	100.0	96.6	7.4	0.81	0	0.0%	—	—	—
2000	23-25	May 31-June 20	521	509	97.7	113.4	12.5	0.85	12	2.3%	146.8	28.6	0.88
2001	22-26	May 24-June 27	447	441	98.7	95.5	7.4	0.85	6	1.3%	97.7	8.1	0.85
2002	23-24	May 31-June 13	243	240	98.8	112.9	12.5	0.86	3	1.2%	153	30.2	0.84
mean (1993-2002)			3,512	3,458	98.5	111.2	12.7	0.88	54	1.5%	140.8	27.8	0.89

Appendix B2.–Juvenile coho salmon releases into Hidden Lake, 1988–1991.

Release Year	Broodstock	Species Stocked	Life Stage[a] fry	fingerling	presmolt	Total Stocked
1988	Big Kitoi	Coho		137,585		137,585
1989	Big Kitoi	Coho		239,817		239,817
1991	Big Kitoi	Coho		250,889		250,889

[a] Fry are released from April to July at up to 200% of emergent size (normally 0.15 to 0.5 g depending on the stock). Fingerling are released from June to September at a size of >200% to <2100% of emergent size (normally 0.3 to 5.25 g depending on the stock). Pre-smolt are released from August to November at a size of >2100% of emergent size but not yet at the physiological stage of smolting (normally 5 to 13 g).

Appendix B3.–Juvenile sockeye salmon estimates based on hydroacoustic fish population surveys of Hidden Lake, 1994–1998 and 2000–2001.

Sample		Sockeye Salmon Estimates[a]		
			95% Confidence Interval	
Year	Month	Number	Low	High
1994	October	91,181	63,700	118,662
1995	November	75,149	35,690	114,608
1996	May	34,347	8,084	60,610
	July	21,241	12,264	30,218
	October	175,154	111,678	238,630
1997	May	103,310	51,157	155,463
	June	25,659	4,603	46,715
1998	April	115,768	90,556	140,980
1999	ND	ND	ND	ND
2000	May	107,390	84,335	130,445
2001	May	24,444	17,719	31,169

[a] Townet surveys were discontinued due to sockeye avoidance of the trawl net.

Appendix B4.–Sockeye smolt stocking and adult survival estimates by age and stocking year, 1992–2009.

Juvenile Stocking		Adult Fresh Water Age							Fry to Adult
Year	Number	No. of Age 1.	Percent Survival	No. of Age 2.	Percent Survival	No. of Age 3.	Percent Survival	Total Adults Produced	Survival (%)
1992	260,000	47,371	18.2	1,923	0.7	0	0.0	49,294	19.0
1993	554,600	18,539	3.3	822	0.1	0	0.0	19,361	3.5
1994	250,000	9,631	3.9	620	0.2	0	0.0	10,251	4.1
1995	98,650	6,643	6.7	3,351	3.4	0	0.0	9,994	10.1
1996	390,800	46,883	12.0	1,474	0.4	0	0.0	48,357	12.4
1997	455,200	37,044	8.1	123	0.0	0	0.0	37,167	8.2
1998	340,400	17,566	5.2	1,058	0.3	0	0.0	18,624	5.5
1999	310,000	31,882	10.3	1,074	0.3	0	0.0	32,956	10.6
2000	504,400	49,897	9.9	4,066	0.8	0	0.0	53,963	10.7
2001	315,500	15,480	4.9	109	0.0	0	0.0	15,589	4.9
2002	51,600	331	0.6	37	0.1	0	0.0	368	0.7
2003	31,000	724	2.3	117	0.4	0	0.0	841	2.7
2004	70,700	2,108	3.0	657	0.9	0	0.0	2,765	3.9
2005	188,342	6,417	3.4	289	0.2	0	0.0	6,706	3.6
2006	421,668	2,468	0.6	20	0.0	– [a]	– [a]	– [a]	– [a]
2007	500,307	665	0.1	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]
2008	353,801	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]
2009	254,030	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]	– [a]
mean (1992-2005)		20,751	6.6	1,123	0.6	0	0.0	21,874	7.1

[a] Awaiting adult returns.